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THE COMMUNICATION PATTERNS OF ENGINEERS WITHIN AN SME IN 2012

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ABSTRACT
The communication patterns of engineers has been well researched over the past decades. However, due to the rise of new communication technologies and their speed of inception within society, it can be argued that this research could be less relevant to modern communication patterns of engineers. In addition, the engineers may have a preference on the communication technology used depending on the subject or purpose of the communication. Therefore, this paper discusses the results from an exploratory study that has investigated the communication patterns of engineers within an SME in 2012. The instances of communication, subject of communication and the purpose of communication were of particular focus. From this, a list of subjects and purposes for the communications was generated, which engineers were able to assign their communication to.

Keywords: communication, human behaviour in design, information management, design practice, engineering design communication

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1 INTRODUCTION

It is well established that communication is intrinsic to almost all engineering design activities and there is a wide consensus that engineers spend a significant proportion of their time communicating with one another (Tenopir and King, 2004 p.30, Perry and Sanderson, 1998). Ellis and Haugan, (1997) Zipperer, (1993) and Wood and DeLoach (2001) reveal that engineers make considerable use of communication channels to seek for information as colleagues are seen as quick and trustworthy sources. These earlier findings still remain the case in todays digital workplace, where it has been shown that engineers still prefer to communicate with their colleagues to seek information as they are often able to better understand the context surrounding their needs despite the introduction of modern search tools (Allard et al. 2009).

It has also been shown that engineers rely heavily on communications to *'fill in the gaps'* left by formal documentation and processes (Brown and Duguid, 2000). Dong, (2005) and Liebowitz and Wright (1999) shows that almost all successful design teams contain high levels of communication as it creates and maintains a shared understanding of the product and product development process. In addition, Adler, (1995) and Daft and Lengel (1986) discuss how communication plays a key role in reducing uncertainty and what is argued as *'needless'* uncertainty as the information/knowledge is available but engineers are unable to find it. Finally, McKelvey and Page (1990) highlight how effective communication is crucial in enabling engineers to ensure conclusions and decisions are well informed.

Given the importance of engineering communication it is surprising that much of the published research within the field was undertaken in the 1990s – early 2000s (Tenopir and King, 2004). During this time, it was seen that engineers' main communication channels were Face-to-Face and the Telephone with a relatively slow rise in the prominence of E-Mail when compared to other industries. These findings were justified by the proposition that communication trends within engineering tend to lag behind other hi-tech/service industries and society itself. With this assumption and the age of the research compared to the rate of change of communication technologies, this paper seeks to explore if and how the communication channels and patterns have changed/evolved. In addition, this paper also looks to explore the subject and purposes of communication by engineers as the authors have a particular interest in verifying the elicited purposes from a review of engineering communication literature (Gopsill et al, 2012, In Review) as well as providing feedback as to there suitability as tags to be employed within a Social Media tool (see, Gopsill et al, 2013). To achieve this, an exploratory study of an engineering Small Medium Enterprise (SME) is undertaken. The paper begins with a brief description of the company alongside the methodology. The results are then discussed and compared to past research within the field.

2 THE STUDY

This section describes the company in which the study was performed and the methodology for capturing and reasoning behind the type of data being captured.

2.1 Company Description

The company is an SME located in Bath, United Kingdom and its focus is on providing health care and assistive products to aid people with disabilities in their daily living. These range from products with few components, fully electronic-based products to fully motorised products. Their employment ranges from 20-40 people (dependent upon workload and contractual agreements) of which approximately two thirds have an engineering background. It can be seen from their broad range in product portfolio, that the engineers are involved in multiple disciplines and constantly changing product complexity. The company is based within a single building consisting of two floors with engineering workshops and test space on the 1st and offices on the 2nd.

2.2 Methodology

As with previous studies within the field of engineering communication research, a survey was used as the capture method. The survey was online based and performed at the *'End*-of-*Day'* for a period of a week by the engineers within the company. This survey was performed twice with a gap between the weeks of approximately one month, thus leading to two sets of results, one for each week. Performing the survey twice provides the opportunity to see whether there are considerable differences in

communication between working weeks of the company. This is very important as Wasiak at al. (2011) have shown that the proportion of the types of communication varies greatly depending upon the Product Development stage that they are in. The survey is illustrated in figure 1 and covers three areas: Instances, Subject and Purpose of communications.

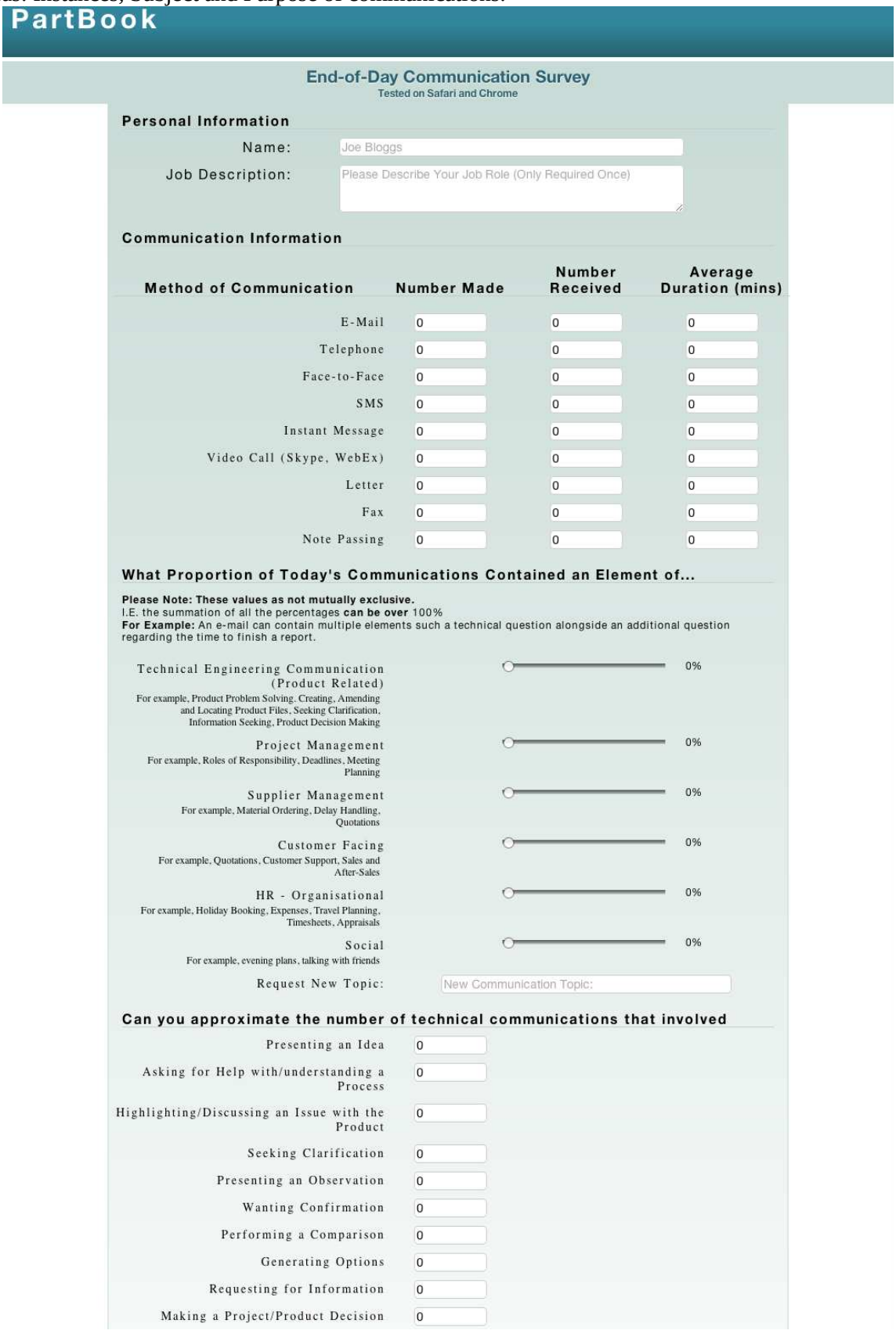

Figure 1: Representation of the Initial Survey Form Used

2.2.1 Instances of Communication by Channel

Engineers were required to enter the number of times they made/received a communication using the various channels listed in table 1. This provides an indication to the level of communication through the company and the proportion taken up by each channel. There are limitations in determining whether a communication continues from one channel to another and whether using a communication was a reply and therefore not generating a new communication topic. However, due to the need for the survey not to intrude too much into the workload and previous surveys using the same metric, it has been deemed suitable for comparative work.

Table 1: Communication Channel Categories

Communication Channel
E-Mail
Telephone
Face-to-Face
SMS
Instant Message
Video Call
Letter
Fax
Note Passing

2.2.2 Subject of Communication

To understand the variety of communications contributed to by engineers, this paper proposes five subjects of communication (Table 2), which are an aggregation of types described by Wasiak et al., (2011) Tenopir and King, (2004, p.39) and Gopsill et al. (2012). Engineers were required to indicate proportionally, how many communications contained the following subjects of communication. It was strongly enforced that these proportions were not mutually exclusive and that communications have the potential to have a multiplicity of subjects. In addition, the engineers were given an opportunity to add or request amendments to the definitions of the subjects. The study wanted to see whether these subjects cover all communications within engineering and the ability for engineers to be able to distinguish between them.

Table 2: Proposed Subjects of Communication

Term	Examples
Engineering Design Communication	Product Problem Solving, Creating, Amending and Locating Product Files, Seeking Clarification, Information Seeking and Product Decision Making.
Project Management	Roles of Responsibility, Deadlines and Meeting Planning
Supplier Management	Material Ordering, Delay Handling and Quotations
Customer Facing	Quotations, Customer Support, Sales and After-Sales
HR/Organisational	Holiday Booking, Expenses, Travel Planning, Timesheets and Appraisals
Social	Evening Plans, Talking with Friends and *'the football last night'*

2.2.3 Purpose of Engineering Design

Although there are a number of subjects for a communication, Engineering Design Communication is of key focus to the authors. Past research has identified that almost all EDCs have a direct purpose (Wasiak et al. 2011, Maiden and Bright, 1996). Table 3 presents the aggregation of the various purposes of EDC that have been identified within an extensive review of the literature (Gopsill et al, 2012, In Review). These have been used within the survey alongside the opportunity for the participants to add new purposes, so that it can be determined whether this table represents a complete list of purposes for an EDC communication and whether the engineers were able to distinguish their EDCs between these ten categories.

Table 3: Proposed Purposes of EDC Identified within the Literature

No.	Purpose of Communication	Description	References
1	Idea	The engineer wants to show something potentially new	Milne and Leifer (2000) Wasiak et al. (2011)
2	Help	The engineer wants to solve a process problem	Ahmed and Wallace (2004)
3	Issue	The engineers wants to solve a product problem	Wasiak et al. (2011) Ahmed and Wallace (2004)
4	Clarification	The engineer wants to double-check their knowledge on a subject	Baya and Leifer (1995) Wasiak at al. (2011) Milne and Leifer (2000) Ahmed and Wallace (2004) Perry and Sanderson (1998)
5	Observation	The engineer wants to highlight an artefact of potential interest	Wasiak et al.,(2011) Ahmed and Wallace (2004)
6	Confirmation	The engineer wants to ensure the artefact is correct	Aurisicchio et al. (2010) Milne and Leifer (2000)
7	Comparison	The engineers wants to converge upon a solution	Aurisicchio et al. (2010) Baya and Leifer (1995) Eckert et al. (2001)
8	Option Generation	The engineer wants to generate a number of solution to a problem	Aurisicchio et al., (2010) Eckert et al. (2001)
9	Information Request	The engineer wants to locate/receive information with regards to a particular subject	Baya and Leifer (1995) Wasiak et al. (2011) Aurisicchio et al. (2010) Milne and Leifer (2000) Ahmed and Wallace (2004)
10	Decision	The engineer want to propose a decision that they are about to make and want other engineers' input	Toye et al. (1993) Eckert et al. (2001)

3 RESULTS AND COMPARISON

This section provides the results and discussion of the results from the survey, with comparison to previous research where applicable. The study managed to achieve an 87% return rate for survey one and 50% return for survey two, thus giving a combined return percentage of 70% with an n = 30. The main factors for the drop in return percentage was through engineers being on holiday and/or away from the office. The results are summarised with respect to Instances, Subject and Purpose of communication.

3.1 Instances of Communication by Channel

The proportion of communication through the various communication channels of the SME from the aggregation of the surveys from week A and week B is shown in figure 2. Although, the survey presented nine channels for communication to flow, only three were significantly used. It can be seen that E-Mail is the most frequently used communication channel, followed by Face-to-Face and then the Telephone. Looking at the overall proportions of communication made/received, it can be seen that it is consistent between the two weeks. The almost even proportion supports the view of engineering as a highly collaborative activity (Bellotti and Bly, 1996) where instances of communication made/received are even across the company. E-Mail (and more significantly E-Mail received) takes up a high proportion of the instances of communication and as it often used for distributed communication, it is argued that these communications are with external sources for information gathering. In comparison, Face-to-Face made is greater than received and this could be indicative of engineers receiving the majority of information through E-Mail, which is then discussed between colleagues through Face-to-Face.

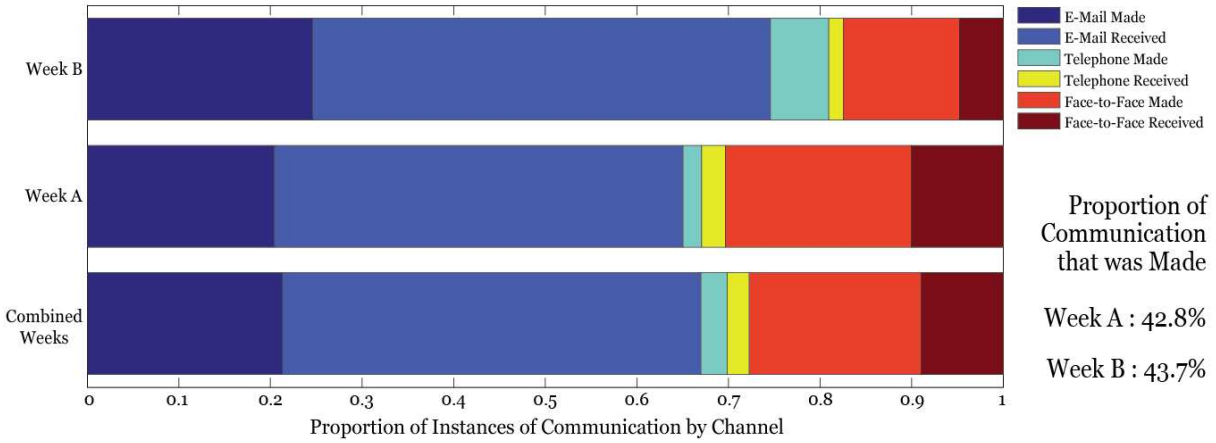

Figure 2: The Proportion of Instances of Communication within the Company

Previous research has shown that communicating through Face-to-Face represents 40% of engineers' instances of communication (Tenopir and King, 2004 p.30), however the two weeks of surveys have shown a decrease and Face-to-Face now represents approximately 30% of an engineers communication instances. Vest et al. (1996) highlights that engineers external communication had often been through the use of the Telephone (up to 50%) and the results from this survey shows that Telephones prominence has been greatly reduced and further, as Face-to-Face has also reduced, revealing how important E-Mail has become as a method of communication.

3.2 Subject of Communication

The proportions of communications for each individual survey across both weeks that contain the various subjects outlined in 2.2.2. is shown in figure 3. It is important to re-iterate that the subjects are mutually exclusive and each has been measured against the total communication instances that the engineer has been involved in that day (i.e. What proportion of communications contained subject X?). Therefore, values >100% will indicate a multiplicity of subjects within the communications, 100% would be indicative of single purpose communication and <100% would indicate incompleteness in being able to distinguish the subject/s of the communication.

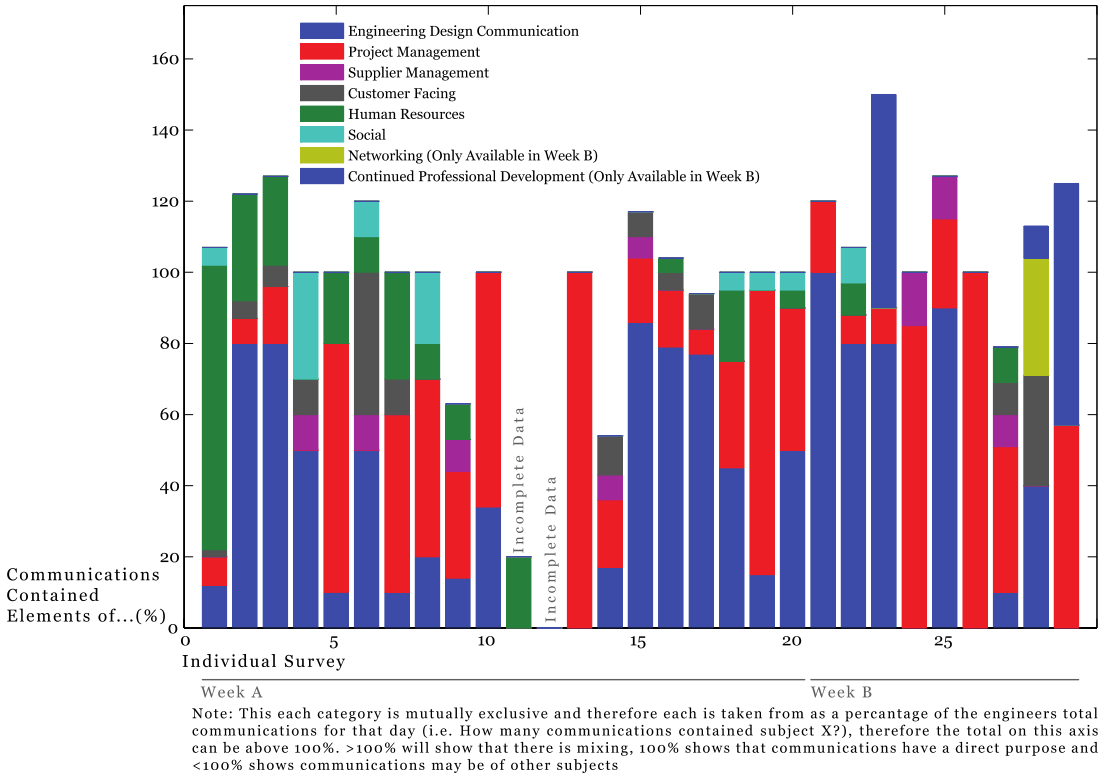

Figure 3: The Proportions of Subjects contained within the Instances of Communications for each completed survey

Week A contained a level of incompleteness and feedback from the engineers proposed two additional subjects of communications; Networking and Continuing Professional Development (CPD). Networking has been described as communication that presents the opportunity to maintain their social network and visibility within the company's social structure. CPD is described as the communications involved in aiding career development through external accreditation (for example, becoming chartered and/or additional qualifications). Placing these within the survey for Week B showed an increase in the summation of the proportions. In addition, no other subjects were requested in Week B and therefore this combination of results provides evidence to suggest that engineers can effectively categorise their communication with the list of subjects.

Comparing the proportions of communications containing the various subjects from each individual survey highlights the varied nature of communication of engineers within an SME. This may seem a logical conclusion, as the size of company would require engineers to be involved in many aspects of the companies' activities for them to succeed. Even though there is a great variety in the proportions of subjects, it can be seen that Engineering Design Communication, Project Management and to a certain extent Human Resources are the main subjects that engineers communications contain. Finally, looking across all the surveys, it can be seen that almost all are within the range of 80-120%, which as mentioned previously above, is indicative of most engineers' communication containing a single subject.

Wasiak et al's. (2011) analysis of e-mail content within an engineering project shows how the proportions of the types (as referred to in their study) of communications is affected by both the individual and over time, thereby supporting the variety that is present within this result. Tenopir and Kings' (2004, p39) study on an engineers high-level activities are comparable to the subjects presented here and the results show that engineering and management activities are the main contributor to an engineers workload and thus, it is logical to see that EDC and Project Management are the main subjects.

3.3 Purpose of Engineering Design Communications

The proportion of the instances of the purposes behind the creation of an Engineering Design Communication to the total instances of EDCs with weeks A and B expressed separately is shown in figure 4. During both weeks, no suggestions were made to add any additional purposes of the EDCs and thus can be considered as an indicator to the completeness of the purposes proposed in table 3. This is further supported by the engineers making use of all the available terms, which indicates that every term within table 3 is requried. In addition, it shows that the engineers were able to distinguish EDC from one another based upon their purpose. These terms could have great potential in being able to organise EDCs within a computer-mediated environment. Comparing the results from both weeks may suggest that there is a consistency in the proportions of the various purposes of EDC being made, however due to the size of the dataset, no statistical significance can be achieved.

Kwasitsu's (2003) study on information seeking behaviour shows that approximately 50% of engineers communications involve solving a problem and this is comparable to combining Help (solving a process issue) and Issue (solving a product issue), which is in the region of 25–35%. In addition, communicating an idea, engineers spent around 14%, which is consistent with this study that shows 12-18% of EDCs concerned ideas.

4 LIMITATION AND KEY RESULTS

Although these results present an insight into the communication practices of engineers within an engineering SME in 2012, it is important to note the limitations of the metrics generated. Therefore this section discusses the limitation of the above metrics and highlights the key results that can be drawn from the study.

4.1 Instances of Communication

The instances of communication metric cannot be taken as the literal value even though it does provide an indication of the level of use each channel within the company. This is because it is a challenge to be able to know whether one is creating a new communication, contributing to or continuing a communication through an alternate channel. The handling of a communication can vary greatly depending upon the channel chosen and this can aid or hinder the recognition of one creating a new communication, contributing or the continuation of a past communication. In addition,

communications may start within one channel and transition to another channel, leading to more confusion. Finally, the accuracy of the capture is limited to the engineers being able to effectively record the number of communications during the day and be able to report them back at the *'end*-of-*day'*. Therefore, the instances of communication metric can only be considered as an indicator of use of the various methods of communication rather than the ability to trace the exact number of communications.
Thus, the key result is that engineers still make considerable use of Face-to-Face (~30%) alongside E-Mail (~65%) communication channels, which has taken over the use of Telephone (~5%) for distributed communications, and that there is an consistent level of making/receiving (43%/77%) communication showing the highly-collaborative nature of engineering within the company.

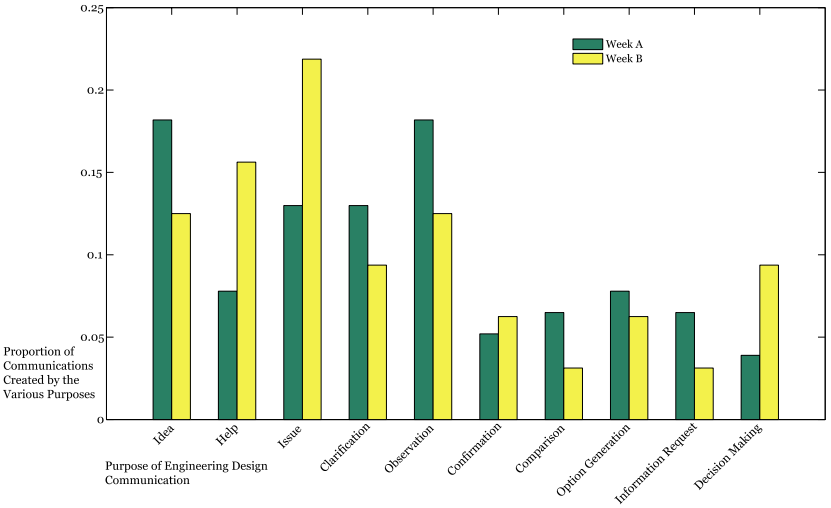

Figure 4: Proportions of Purpose of the Engineering Design Communication

4.2 Subject of Communication

In the case of the subject of communication, again there are difficulties in the engineers being able to effectively post-rationalise the communications they have had at the 'end-of-day'. However, ensuring that each subject was considered separately in relation to whole proportion of communications an engineer had during the day. It can be therefore said that the key results are:
- The subjects of communication in table 2 can effectively represent all communications within an SME in 2012.
- Engineering Design Communication, Project Management and Human Resources are the main contributing subjects.
- Engineers' subjects of communication vary greatly from day-to-day, week-by-week.
- Almost all communications are focused upon a single subject.

4.3 Purpose of Engineering Design Communication

The final metric has been the identification of the purpose of each instance of EDC the engineer has had during the day. Again, post-rationalisation and memory may lead to inaccuracies on the level of instance however as this metric considers the engineers thought-process on *'why'* they wished to have an EDC and therefore they are best suited to distinguish their communications by this measure.
Thus, the key results is that engineers were able to distinguish their EDCs against the ten purposes of EDC shown in table 3 and these have further potential for one wishing to support EDC.

5 CONCLUSION

This paper reports upon the results from a survey used to understand the communication patterns of engineers within an SME in 2012 across two separate weeks. It has been highlighted that communication is fundamental to engineering design and supports almost all engineering design activities, therefore ensuring the right communication are being had between the right engineers can be seen as key to supporting engineering design. Although there has been much past research on understanding the communication patterns of engineers, this has been mainly performed over a decade ago and it has been argued that the rise in new communication technologies may have led to changes

in the communication patterns of engineers. Therefore, this exploratory study looked to understand the communication patterns of engineering within an SME in 2012 as well as provide an opportunity to explore the subjects of communication and purposes behind Engineering Design Communication.
The results have been presented, comparisons made to previous communication pattern research and limitations of the metrics discussed, leading to five key results:

- Engineers still make considerable use of Face-to-Face (~30%) alongside E-Mail (~65%) communication channels, which has taken over the use of Telephone (~5%) for distributed communications, and that there is an consistent level of making/receiving (43%/77%) communication showing the highly-collaborative nature of engineering within the company.
- The subjects of communication in table 2 can effectively represent all communications within an SME in 2012.
- Engineering Design Communication, Project Management and Human Resources are the main contributing subjects.
- Engineers' subjects of communication vary greatly from day-to-day, week-from-week.
- Almost all communications are focused upon a single subject.
- Engineers were able to distinguish their EDCs against the ten purposes of EDC shown in table 3 and these have further potential for one wishing to support EDC.

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REFERENCES

Paul S. Adler. Interdepartmental interdependence and coordination: The case of the design/manufacturing interface. Organization Science, 6(2):pp. 147–167, 1995. ISSN 10477039.
URL http://www.jstor.org/stable/2635119.
S. Ahmed and K. M. Wallace. Identifying and supporting the knowledge needs of novice designers within the aerospace industry. Journal of Engineering Design, 15(5):475–492, 2004. doi: 10.1080/09544820410001708430.
URL http://www.tandfonline.com/doi/abs/10.1080/09544820410001708430
Suzie Allard, Kenneth J. Levine, and Carol Tenopir. Design engineers and technical professionals at work: Observing information usage in the workplace. Journal of the American Society for Information Science and Technology, 60(3):443–454, 2009. ISSN 1532-2890. doi: 10.1002/asi.21004.
URL http://dx.doi.org/10.1002/asi.21004
Marco Aurisicchio, Rob Bracewell, and Ken Wallace. Understanding how the information requests of aerospace engineering designers influence information-seeking behaviour. Journal of Engineering Design, 21(6):707–730, 2010. doi: 10.1080/09544820902877583.
URL http://www.tandfonline.com/doi/abs/10.1080/09544820902877583
V. Baya and L. Leifer. Understanding design information handling behavior using time and information measure. Design Engineering Technical Conferences, pages 555–562, 1995.
J.S. Brown and P. Duguid. Balancing act: Capturing knowledge without killing it. Harvard Business Review. May June, 2000.
Victoria Bellotti and Sara Bly. Walking away from the desktop computer: distributed collaboration and mobility in a product design team. In Proceedings of the 1996 ACM conference on Computer Supported Cooperative Work, CSCW'96, pages 209-218, New York, NY, USA, 1996, ACM. ISBN 0-89791-765-0. doi: 10.1145/240080.240256. URL http://doi.acm.org/10.1145/240080.240256.
Richard L. Daft and Robert H. Lengel. Organizational information requirements, media richness and structural design. Management Science, 32(5):pp. 554–571, 1986. ISSN 00251909.
URL http://www.jstor.org/stable/2631846.
Andy Dong. The latent semantic approach to studying design team communication. Design Studies, 26(5):445 – 461, 2005. ISSN 0142-694X. doi: 10.1016/j.destud.2004.10.003.
URL http://www.sciencedirect.com/science/article/pii/S0142694X05000050.
D. Ellis and M. Haugan. Modelling the information seeking patterns of engineers and research scientists in an industrial environment. Journal of documentation, 53(4): 384–403, 1997.

J.A. Gopsill, H. McAlpine, and B. J. Hicks. Learning from the lifecycle: The capabilities and limitations of current product lifecycle practice and systems. In International Conference on *Engineering Design ICED'11*, 2011.
Lishi Kwasitsu. Information-seeking behaviour of design, process, and manufacturing engineers. Library & Information Science Research, 25(4):459 – 476, 2003. ISSN 0740-8188. doi: 10.1016/S0740-8188(03)00054-9.
URL http://www.sciencedirect.com/science/article/pii/S0740818803000549.
J Liebowitz and K Wright. Does measuring knowledge make 'cents' ?? Expert Systems with Applications, 17(2):99 – 103, 1999. ISSN 0957-4174. doi: 10.1016/S0957-4174(99)00027-5
URL http://www.sciencedirect.com/science/article/pii/S0957417499000275.
N.A.M. Maiden and B.P. Bright. Recurrent communication patterns in requirements engineering meetings. In Enabling Technologies: Infrastructure for Collaborative Enterprises, 1996. Proceedings of the 5th Workshop on, pages 208 –213, jun 1996. doi: 10.1109/ENABL.1996.555223.
Richard D. McKelvey and Talbot Page. Public and private information: An experimental study of information pooling. Econometrica, 58(6):pp. 1321–1339, 1990. ISSN 00129682.
URL http://www.jstor.org/stable/2938318.
A. Milne and L. Leifer. Information handling and social interaction of multi-disciplinary design teams in conceptual design: A classification scheme developed from observed activity patterns. In *Proceedings of DETC'00 ASME Design Engineering Technical Conferences*, 2000.
Mark Perry and Duncan Sanderson. Coordinating joint design work: the role of communication and artefacts. Design Studies, 19(3):273 – 288, 1998. ISSN 0142-694X. doi: 10.1016/S0142-694X(98)00008-8. URL http://www.sciencedirect.com/science/article/pii/S0142694X98000088.
Carol Tenopir and Donald W. King. Communication Patterns of Engineers. Wiley-IEEE Computer Society Pr, 2004. ISBN 047148492X.
G. Toye, M.R. Cutkosky, L.J. Leifer, J.M. Tenenbaum, and J. Glicksman. Share: a methodology and environment for collaborative production development. In Enabling Technologies: Infrastructure for Collaborative Enterprises, 1993. Proceedings., Second Workshop on, pages 33 –47, apr 1993. doi: 10.1109/ENABL.1993.263065.
D. Vest, M. Long, and T. Anderson. Electrical engineers' perceptions of communication training and their recommendations for curricular change: results of a national survey. Professional Communication, IEEE Transactions on, 39(1):38–42, mar 1996. ISSN 0361-1434. doi: 10.1109/47.486046.
J. Wasiak, B. Hicks, L. Newnes, C. Loftus, A. Dong, and L. Burrow. Managing by e-mail: What e-mail can do for engineering project management. Engineering Management, IEEE Transactions on, 58(3):445 –456, aug. 2011. ISSN 0018-9391. doi: 10.1109/TEM.2010.2090160.
Mark Wood and Scott DeLoach. An overview of the multiagent systems engineer- ing methodology. In Paolo Ciancarini and Michael Wooldridge, editors, Agent-Oriented Software Engineering, volume 1957 of Lecture Notes in Computer Science, pages 1–53. Springer Berlin / Heidelberg, 2001. ISBN 978-3-540-41594-7. URL http://dx.doi.org/10.1007/3-540-44564-1 14.10.1007/3-540-44564-1 14.
L. Zipperer. The creative professional and knowledge. Special Libraries, 84:69–69, 1993.
URL http://bubl.ac.uk/archive/journals/spelib/v84n0293.htm.